STABILITY

THE SEAMAN'S SAFEGUARD.

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THE SEAMAN'S SAFEGUARD:

Being a Contribution towards eradicating the ignorance that occasions annually the loss of very many valuable lives.

BY

E. GARDINER FISHBOURNE,

Vice-Admiral, C.B.

"WISDOM and knowledge shall be the stability of thy times, and strength of salvation: the fear of the Lord is His treasure."—
ISAIAH xxxiii., 6.

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1878.

Sydenham, S.E.,
8th March, 1878.

DEAR ADMIRAL FISHBOURNE,

I have just read with great pleasure your explanation of the True Nature and Sources of That Sea Going Stability which is of the Greatest Value to Ships and Seamen, and the lives and

Page 17, 3rd line, omit "only."
Page 19, last line but one, G should be small *g*.
Page 55, 18th line, "move" should be *more*.
,, Fig. 15 should be 17.

who do so rather according to the Old Customs of the Sea, than according to Abstract Mathematical Disquisitions.

It is plainly to the interest of Merchant, Ship Owner, Underwriter, and Sailor, that the ignorance or prejudice which sends to Sea Crank Ships with Scant Seaboard, and Feeble Stability should be eradicated; and that the plain Common Sense and

Common Honesty of only sending to Sea such Ships as can Stand up Steadily under Strong Winds, and roll gently with Heavy Seas, and come safely out of Waves and Storms with no other Enemies to fear and avoid but rocks and shoals—should be so widely diffused as to become part of our National Character and Seafaring Custom.

Wishing you the success you deserve in your Patriotic Work,

I remain,

Sincerely yours,

J. SCOTT RUSSELL.

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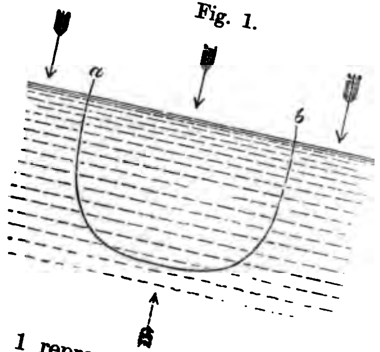
According to accepted law, all things on the earth are attracted towards its centre—water is no exception to this; therefore every globule presses down with the force of its weight towards the centre of the earth, but is supported in the position in which it is found by those below and around. Every particle is on a line converging towards the earth's centre.

Hence the pressure of the 2nd particle in the series is that of the one above it, with its own weight; of the 3rd, is that of the two above it and its own weight, and so on continuously down to great depths: but this also is true of every series or column of particles; they are all pressing down with the added pressure and tendency inwards, so that if a quantity of them are taken out, the superintendant column on either side, seeking its level, forces in particles to fill up the space. This we see when a body is moved slowly through the water, no real space is left behind, but equally when it is moved faster than the water in, the body will fall at its after end from din support.

Fig. 1.



Let Fig. 1 represent a number of columns of globules or particles, if a skin is inserted, as *a b*, enclosing a certain quantity, that skin will bear the collected pressure of all the particles above it, but the skin will be supported by the downward and resulting upward pressure of the columns of particles all round it.

Now these pressures are uniform and the same in each column at any given depth, consequently the perpendicular pressure up of all the particles may be considered and treated of as if all the pressure was one passing in a line through the centre of figure, though the pressures are all actually on the skin. The former, also, is true of the pressure of the weight downwards when the vessel is at rest and upright.

We can readily make a vessel that would contain exactly a cubic foot of water and weigh it, then by measurement ascertain how many cubic feet of water are contained within any skin, thence we should obtain the weight pressing down, and the force pressing up that sustains all these particles.

Let us now suppose a vessel substituted for this skin; her bottom will take all the pressures up that were borne by the skin, and if a weight is substituted for the water within, its weight also, if of a different form or size than the skin, the same rule will follow, so if we measure the number of cubic feet contained within that part of the *skin* of the vessel that is in the water, and multiply them by the weight of a cubic foot, we have the entire weight of the vessel, both that of the hull and that of the weight, substituted for the water within the hull.

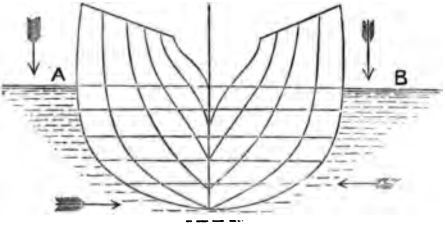
It were easy to mark a dock at its sides with the cubical content at each inch and part of an inch, and if partly filled with water a vessel moved into it would raise the water up on these marks. The difference in the height on these, when she was in and before, would give the cubic contents of the water she displaced, and therefore her weight.

But it would not be always convenient to have docks; moreover, did we have such, that would not suffice, as we require to have this information and much besides before the vessel is built, in order to guarantee success.

We can draw the vessel on paper, in all her external particulars, as the plan of a house, and of requisite dimensions; then the weight of a cubic foot of water would be the foot-rule to measure the quantity of water she would displace up to any water line, or depth she may be sunk to.

For this purpose a body plan is designed, shewing all the external dimensions of the vessel, such as Fig. 2. *A B* is the water-line she shall be

Fig. 2.



brought down to, the other horizontal lines are drawn for the purpose of cutting the vessel, as it were into slices, for perfecting the design; this also facilitates the measurement. The vertical lines represent vertical slices cut across the length for laying off the body for building, each section indicating the size and form of the frame for that part.

Of course this measurement cannot be strictly accurate, for, though this plan cuts the vessel up into squares easy of measurement, there will always be room for some inaccuracy, especially with one calculator as compared with another; besides which there are a number of angular pieces of varying form that increases the difficulty, hence it is wise to leave a margin on the safe side. The inaccuracy however, need not exceed $\frac{1}{30}$ or $\frac{1}{40}$ of the whole.

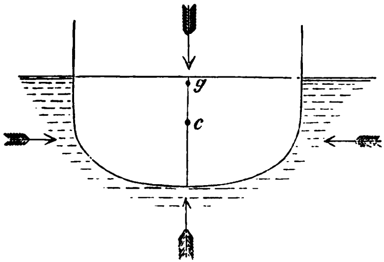
Having obtained the weight of the ship, we have the measure of the force with which she presses down perpendicularly, also the measure of the force that presses upward perpendicularly to sustain her these two forces, being equal and opposite, tend to bring her to rest, and keep her at rest if the water is undisturbed.

These are the two ruling forces in a floating body, let us then consider how these influence the position and safety of a ship in smooth water.

We may argue the whole question on the form of the midship vertical cross section, as the same will apply to all sections, differing only in degree.

Let Fig. 3 represent such a cross section. All the buoyant force may be supposed to be collected in the arrow pressing on the bottom in a line up through the centre of the immersed figure *C*, and all the weight may be considered as collected in *g* and pressing down perpendicularly.

Fig. 3.



For the body on either side of a line passing through *C* being exactly alike, and the water being homogeneous, the pressures must be equal on either side of *C*, so the vessel being at rest and upright the weights must be equally distributed on either side of the centre *g*, and the two forces equal and opposite.

Of course there are pressures on the sides of the vessel, but these under the circumstances are equal and opposite; moreover, as they do not bear any of the downward pressure of the vessel, for the present they may be disregarded.

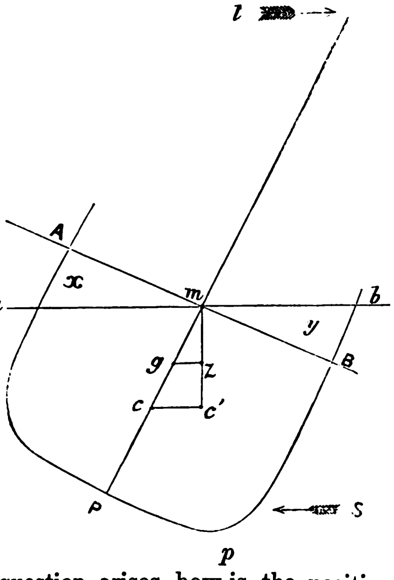
The effect of these two forces is not simply to bring a vessel to rest, but is also to resist her being inclined by a lateral force, such as wind on her sails. The measure of this resisting force is the measure of her stability.

We ought to know the measure of this force at each angle of inclination, for this is the measure of the amount of sail she can carry with effect, and with regard to safety from capsizing.

We will now consider how a general estimate of stability is obtained sufficiently accurate for practical purposes.

Let Fig. 4 represent the midship cross section of a vessel inclined, *A B* to represent the water line when upright, *a b* that when inclined. The collected pressure acting at *P* up through *C*, the centre of immersed figure, and the same acting at *p* up through *C′*, the new centre of figure, when inclined, now the intersection of these two lines of pressure at *m* is what is called the metacentre, *g* is the centre of gravity, or the centre to which all the weight may be considered to be gathered, acting down perpendicularly these two lines of pressure, while the vessel is inclined to the angle represented in figure, at the horizontal distance from each other represented by the lever *Z G*, therefore is the measure of resistance to inclination which the ship is offering at that angle, is the whole weight in tons multiplied by the length of that lever in feet and gives the measure of stability in foot-tons.

Fig. 4.



The question arises, how is the position of C' obtained? By the inclination of the body $B\ m\ b$ or x is forced into the water, and $a\ m\ A$ or x taken out. This alters the shape of the immersed figure from being $A\ P\ B$ to $a\ P\ b$, which is equal to adding x to y, or moving x over a distance equal to moving its centre of gravity to the centre of gravity of y; supposing these two figures to be triangles, that distance is equal to $\frac{2}{3}$ of the vessel's breadth.

The proportion that the cubic contents of x and y and the $\frac{2}{3}$ distance above mentioned, bear to the cubic contents of the whole immersed body, will be the distance that C' will be moved from C, the original centre of figure, at the given inclination, then a perpendicular from the former to the water-line a b, will give the metacentre m, and the horizontal distance from g, the centre of gravity, will give the equilibrating lever $g\ Z$. It will be seen that if g is raised this lever and the stability will be reduced, and if it be lowered $g\ Z$ will be increased, and the stability with it double $g\ Z$, by lowering the centre of gravity, and the stability will be doubled.

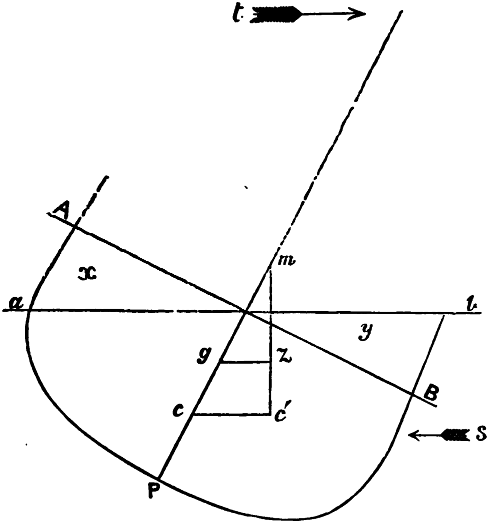
The question is suggested, may we with safety give as much sail to a ship as would produce a pressure equal to the stability?

Certainly not! for that would leave no margin for meeting the effect of sudden squalls, tornadoes, hurricanes, &c., in respect of which warning must be given, that the *suddenness* of these will incline a vessel double the quantity that the same force brought on *gradually* would, therefore that there should be a margin of stability left to meet these contingencies, nor is this the only reason, for there is another inclining force developed by the action of wind, called the wind couple.

When the vessel was at rest the lateral forces were equal, but when sail is set on her with a side wind, its tendency is to blow her to leeward, in which so far as it succeeds it reduces the pressure on the wind side, and increases the pressure on the lee side, from which we have a pressure which may be treated of as collected at the centre of effort or pressure of the sails above pressing her over (see Fig. 4), and the water below acting at its centre $\frac{2}{3}$ of the depth down pressing her keel and lower parts in the opposite direction (see Fig. 4), these constituting a couple to turn her round or incline her; allowance, therefore, ought to be made for this, since the effectiveness of the sails and the helm depend much upon the yielding to side pressure not being too easy, or, in other words, the vessel possessing sufficient stability to stand up against her sail, so that it shall push her forward rather than over, consequently not only for safety but also for efficiency, stability should be fully sufficient. In a word, stability is the life of ships and their crews.

We ought to consider how change of form will influence stability. Thus if we increase the breadth in Fig. 5, leaving the displacement the same, and keeping g at the same distance from the water line.

Fig. 5.



The effect of this will be, first, she will not be so immersed, therefore *C* the centre of figure, will be higher, *x* and *y* will be larger at same angle of inclination, and their centres of gravity will be further apart; therefore, the distance that *C′* will be moved from *C* will be greater, and that distance will be measured off from a higher point, and nearer to g, therefore the metacentre will be higher, the metacentric height greater, the lever $Z\ g$ will be much greater, and the stability proportionably greater; the wind couple also would be less as the wider ship would not be so immersed.

She no doubt could carry more sail, but she would require more sail to drive her, would require more hands, would not be so weatherly, and taking more entirely the motion of the waves, in swinging from a perpendicular to the wave face to a perpendicular to its back, her momentum would be much greater, and make her more uneasy, and subject to greater wear and tear: then she would require a higher freeboard for equal safety.

Fig. 6.

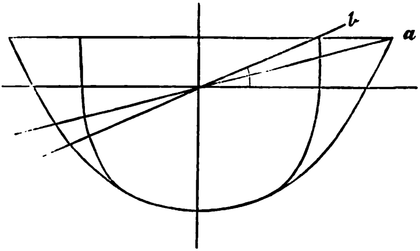


Fig. 6 shows that the wider vessel could not be *inclined to the* same angle if the freeboard was

only the same height. The wide vessel might be heeled to *a*, while the narrow vessel might be heeled only to *b*.

But in truth the question for a sailor is how to make the best of a ship when he has got her; forming the ship is for the architect, therefore we will consider the effects produced on the same ship by changes in the cargo.

We will suppose a ship to be more deeply immersed, or sunk further in the water, by an increase of cargo.

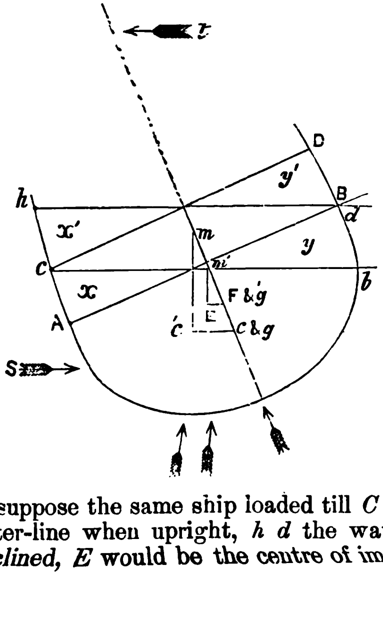
1st, The lower part of the ship being full, any increase of cargo must be added above that already shipped, therefore it must raise the centre of gravity.

2nd, The centre of the immersed figure *C* must go down a quantity equal to half the additional immersion.

3rd, The proportion that the solids of immersion and emersion, *x* and *y*, bear to the whole immersed body will be less, therefore *C'*, the new centre, would be moved out a less quantity than with the lesser cargo, and the stability would be less.

Let Fig. 7 represent a ship under two different conditions of lading. *AB* the water-line, with a medium lading *C b*, that when inclined *C*, the centre of immersed figure, and also the position of the centre of gravity *g*, *C''* the centre of figure when inclined; now, a perpendicular to the new water line *C b* would cut the original line of support at *m*, and *m g* would be the metacentric height, *C′ g* would be the equilibrating lever, which is of considerable length, so her stability would be great.

Fig. 7.



Now suppose the same ship loaded till *C D* was the water-line when upright, *h d* the water-line *when inclined*, *E* would be the centre of immersed figure, and g, the centre of gravity raised, would be at the same point, and E the centre of figure when inclined.

The inclination being equal, x' and y' would be equal to x and y in the former case, but as they would bear a smaller ratio to the whole increased immersed body than to the smaller immersed body, E would move a smaller distance from F than C'' did from C, consequently a perpendicular from E to $h\ d$ would cut so little above g' as to leave the ship only a nominal amount of stability, added to which, the gunwhale having been brought close to the water, a small inclination further would immerse it, when the water would flow in and take away the bouyancy of much or all of x, and with it a further measure of stability; moreover, by this greater immersion, the centre of lateral pressure would be carried further down, at s increase the inclining action of the wind couple. See arrows t and s.

Nor is this all, for by this undue immersion the full lines of the bow would be immersed, reducing her speed and making her difficult to steer, especially when on a wind; all these would be aggravated by any increase of load that was of the nature of a deck load; nor would the increase of weight compensate for the shortening of the equilibrating lever $E\ G$, more especially when the gunwhale was immersed, which it would be at the

B

time it was most necessary for safety that it should not be.

For every reason, then, overloading is most undesirable, not simply as a question of humanity, but also as a profitable speculation; for ships in that condition will not sail so fast; that involves demurrage, greater chances of bad weather, and not so readily answering their helm they will be more likely to collide, and will not so readily escape suddenly discovered danger, or traverse safely intricate navigation; will roll deeper, strain more, ship more water, and be more liable to be thrown on their beam ends; if such leak, even but little, or ship seas, their danger will be great in proportion as their stability is small.

The "Wreck Register" abundantly proves that this is no overdrawn picture, or a thing not likely to occur, for it frequently occurs in vessels, no matter what or how heavy soever the kind of cargo may be with which the vessel is overloaded.

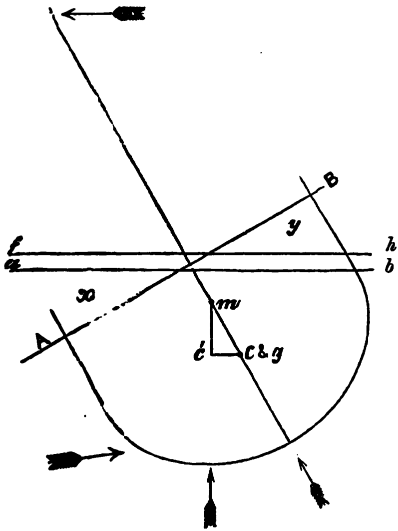
It would appear from the "Wreck Register," that there is an impression that if the kind of cargo be heavy, such as coals or salt or grain, they may be loaded to an extreme degree. That is a very grave error, as by far the greater number of the missing 100 vessels were thus loaded.

In our previous arguments we assumed that the height of side was sufficient, and that the gunwhale *would* not be brought under water ordinarily, but it must be remembered that such is not the general condition, but that it is too common for vessels to be so deeply laden that there is very little side above water, for which reason, and their deficient stability, a small angle of inclination, which is easily arrived at, brings the gunwhale under water; moreover, there are sheeve holes and hinged ports to let water off that may have been shipped, these, too, often admit water, which facilitates the inclination, and tends to give a permanent list to one side.

Let Fig. 8 represent a deeply laden vessel, inclining with her gunwhale under water, the lee side then will be filled with water, the effect of which will be that the whole or part of the hitherto buoyant action of *x* will disappear, so the total displacement would be reduced but for a further change. Ordinarily the taking of *y* out of water by inclination is provided for by the immersion of *x*, but as this disappears the vessel must sink lower, and instead of *a b* being the inclined water line, *f h* will become it.

As a consequence, *C*, the centre of the immersed figure, goes down, so also does *g*, but as *x* disappears, and only a part of *y* is brought out, *C″*, the new centre of the immersed figure, moves out a very small distance from *C*, so a perpendicular from the former to the water-line f h would pass *so near g* as to leave little stability, unless *g* had been brought very low by ballast, or by a very compact cargo stowed low; under any circumstances the stability would be greatly and even dangerously reduced.

Fig. 8.



It must be obvious that, with so little stability as *the above* would entail, and the conseque great inclination, a vessel in that condition could not carry any effective sail, for they would be carried so far over to leeward that the inclination of the plane of the sails from a perpendicular would be so great that their resolved thrust downwards would be so great as to bury her still further, from which she would become unmanageable in a seaway, and in so perilous a condition that only a small wave would be required to complete her capsize.

The conclusions that obviously flow out of what has been shewn are, 1st. That the arbitrary rule of three inches of side above water for every foot of immersion for every vessel is simply nonsense, for the amount which is necessary for safety depends upon the measure of stability that is due to a low centre of gravity. All those recommendations to place the centre of gravity high, on the plea that such reduces the angle of roll, betrays great ignorance, and all recommendations to raise the centre of gravity to ease the vessel in bad weather, unless it has been previously *too* high, comes from men who have mistaken their profession, and involve danger in proportion as they are adopted.

2nd. That water should be kept from coming in upon the deck, especially when the stability is small, as it tends to reduce that dangerously.

3rd. That a high side is requisite for safety in proportion as the centre of gravity is high, and in proportion as the breadth is great.

4th. That a very low side is never safe, except with a very low centre of gravity, or where there is a long poop and forecastle, as in galiots and other vessels that have the accommodation for captain and crew above deck.

So much depends on the position of the centre of gravity that we will discuss it still further.

It is becoming common to fit ships with ballast tanks, and to keep them empty when the vessel is loaded, placing the cargo *above* them. This, of course, raises the centre of gravity, and proportionately reduces the stability, and with it the effectiveness of sails and of the helm, which again increases the danger of the vessel being thrown on her beam ends, and, indeed, the "Wreck Register" records that several have been thus thrown on their beam ends, and some of them finally foundered; and several cargo vessels have been found so to roll, much more to one side than the other, that it has been thought that the cargo had shifted, and had given them a permanent list, but on arriving in port it has been found that there has not been any substantial shift of cargo.

This condition arises from the high centre of gravity, and little stability arising from which; *they roll* deeply when on the face of a wave, and *there is* a want of power to bring them up again from it to produce a roll back; this condition, no doubt, facilitates a shift of cargo, and does produce it to some extent, even when all the parliamentary precautions are taken, owing to the grain being shaken closer together against the lower side of the vessel and against the sustaining boards; this, though small, is serious when the stability has been small.

Indeed, the insurance ought to be voided when the cargo is placed on these tanks without previously filling them, as this involves all the danger of being thrown on the beam ends, with its very dangerous consequences to life and property.

Another danger arises from not duly considering the effects of difference in form. We have heard of ten vessels being capsized when light, having discharged their cargoes without taking other or ballast, at the same occasion, by a sudden squall with a consequent sudden wave—this shows how important form is in merchant vessels, as it will occur that they must discharge all their cargo, and may require to be taken to another port for cargo or ballast.

Under these circumstances rising floors should be avoided if possible, but when they exist, on no account should vessels of that form have their cargoes entirely discharged without taking in ballast.

For, *take two* vessels, as Figs. 9 and 10, of equal capacity and weight of hull, *g* would sink deeper in the water, the centre of gravity of each would be about in the centre of the *whole* figure; suppose them now inclined to the same angle, in that it is evident that x and y of Fig. 10 would be much greater than x' and y' of Fig. 9, and the centres of gravity of these solids of immersion and emersion much further apart, consequently C' would move much further out from C in Fig. 10 than in Fig. 9, therefore the stability of Fig. 10 would be much greater than that of Fig. 9. Moreover, from the greater immersion of Fig. 9, the inclining force of the wind couple acting at *s* would be greater, so Fig. 10 would be safe under the above circumstances, when Fig. 9 would capsize. Iron vessels with their lighter bottoms would be in greatest danger.

I designed surf boats of comparatively small breadth with flat floors, and they proved to be as safe empty as loaded, while others with rising floors capsized.

The following ship will illustrate the above, as she had a remarkably flat floor, and a beam of only 1 to 6 in length, while it will illustrate the danger which arises from changes in the kind of cargo.

A fine ship of 2,500 tons, that was launched with topgallant yards across, and experienced a gale in that condition in the river, stood up under *its pressure*, took in 342 tons of dead weight,

Fig. 9.

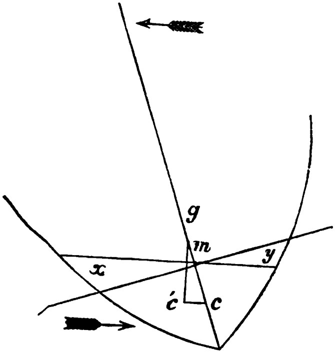
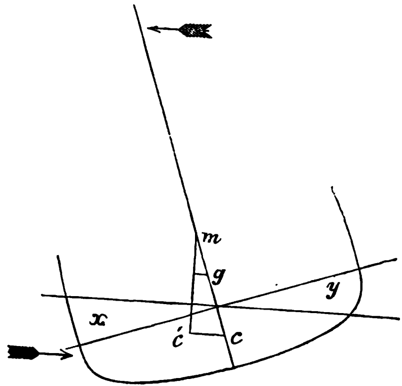


Fig. 10.



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together with 130 tons of permanent ballast, and 3,180 tons of measurement goods; she proved herself then to be a good serviceable stiff ship in heavy weather, sometimes under close-reefed topsails.

Having discharged all her cargo, except 127 tons of hoop iron and her 130 tons of ballast, she again in heavy squalls proved herself to be a very stiff ship.

She then took in 175 tons of ballast below the cealing (having discharged all her outwardbound cargo), 12,339 bales of cotton, 1,800 bags of linseed, 3,800 bags of myro-balms, and 1,600 bundles of cork, the last of these articles being distributed throughout the ship to fill up broken stowage.

She had hardly left port when it was discovered that she was very deficient in stability; at first she experienced light winds and carried skysails, sailing nearly on her side. After having been some time out, the wind increased, sail was reduced to topgallant sails; then squally; the captain ordered mizen topgallant sail to be taken in, then other topgallant haulyards to be let go; she was heeling over so much that the water was entering through the sheeve holes in the upper works, heeling so that it was reported at the inquiry that it was too much to admit of the sail being taken off her. They put the helm up, and she quietly turned over and soon went down; the captain and many of the crew were drowned.

The judgment was, that she had enough ballast, therefore enough stability; this evidently is erroneous. A vessel's stability ought to be such that sails or masts even should go before she could be upset. The report also stated that she was lost through carrying too much sail—no doubt too much for a crank ship!

The vessel was badly handled, the helm should have been put down to shake the wind out of the sails, when they did so, the weather topsail braces should have been rounded in, and the topsail haulyards let go; this would have saved the ship and crew. It is implied in the report that the sheets could not be got at to let them go, but the action of the helm would have given instant relief.

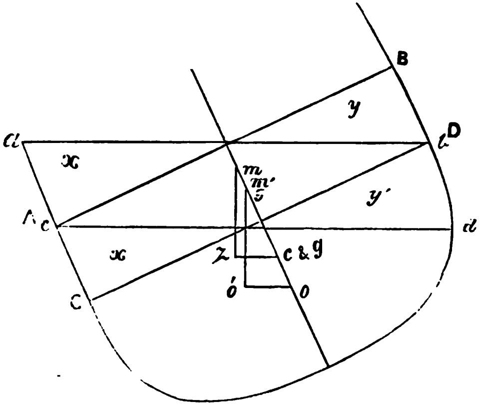
They ought to have known that, inclining as she was, she was so immersing the bluff of her lee bow, and bringing the full lines of weather bow out, that her head would be pressed up to windward against the weather helm, also that the effect of the sail, from being carried over so far to leeward by her great inclination, was also to force the head up to the wind by the force acting through the lever *a c* (Fig. 15), *c* being the centre of pressure of the sail; moreover it was wrong to put the helm up at such a crisis, for, had she paid off, the immediate *effect of the sails* on her would have been increased *at a time that it* was too great already.

Let us now consider the two conditions resulting from the cargo, ballast, &c.

Under the circumstances, when she proved herself to be a safe stiff ship, she practically had 470 tons of ballast with 3,180 tons of measurement goods, or nearly ⅓ of the whole cargo, and, judging from the character of exports, the cargo would have been nearly of as great specific gravity as water, therefore, for these two causes, her centre of gravity would have been well down, quite to, if not below, the centre of the immersed figure, and hence her good behaviour.

On the occasion of her failure she took in only 175 tons of ballast, if this was in addition, but it is not so stated, to 130 previously in she would have had only 300 tons, that is, 170 tons less ballast than on the former occasion. Then on the occasion of her failing, her cargo was cotton, much lighter than water even when pressed in bales, and much lighter than her former cargo, and though some of the other articles used to fill up broken stowage may have been heavier, yet as they were largely distributed, and from the form of the vessel must have been distributed, more largely high up, her centre of gravity would have been high, she would probably also, as is usual in cotton cargoes, have had a deck load which would tend to raise the centre of gravity still higher and for all reasons higher than on her former voyage.

Fig. 11.



Let Fig. 11 represents the two conditions *AB*, the water-line when deeply loaded and upright *ab*, that when inclined *C*, the centre of immersed figure, *g* the centre of gravity at same depth, because the cargo is heavy and because that centre is brought lower by 470 tons of compact weight, now a perpendicular through *z*, the centre of immersed figure when inclined, would cut high up at *m*, but *g* being as low as *c z g* would be the *lever of stability*, and therefore her stability would be equal to this long lever multiplied by the greater load, consequently would be very considerable.

Then *C D* would be the water-line when upright with a cotton cargo, *C d* that when inclined, *o* the centre of immersed figure, *o'* that when inclined, but as x' and y' bear a larger proportion to the lighter immersion than to the deeper, *o'* will move out a greater distance from *o* than *o'* or *Z* from *C'*, but being measured off from a point so low down a perpendicular to *c d* would cut so little above, *g* the higher centre of gravity, raised as above described, as to leave her only a nominal lever of stability, then the total weight was less and her stability would have been wholly insufficient, as was proved to be the case and proved fatally.

This ship's proportion of breadth to length being so small, 1 to 6, was a further reason why her centre of gravity should be kept low, as she could have little stability from the small size of x and y the solids of immersion and emersion and as from her great length the inclining effect of the wind couple would be great though not so great as when deeper.

There is another evil that arises from crankness or want of stability that is either not observed or is under estimated, that is the necessity for weather helm that it entails and its evil consequences.

The force of the stream of water that acts on the helm being vastly greatest low down when the helm is necessarily kept constantly a-weather, as it must be when a vessel is inclining under sail with her lee bow pressed down, its resolved thrust is to incline her still more and make it almost impossible to get her off the wind or to wear her, no doubt for this cause the "Monarch" was said to be sometimes an hour in wearing, and the "Bellerophon" is said to be the same, and that after sails had to be set and the head sails taken in, the effect of this probably is less immersion of the bow, and sail is necessary to obtain the stream on the rudder to turn her; in fact there is no one thing to justify little stability, not even a conceit!

The ship in question, under the circumstances of a cotton cargo, not simply to make her safe, but for efficient economic navigation, ought to have had quite 300 tons more ballast low down.

It is not sufficiently remembered that beside the reduction of control by the helm when a shi has so small an amount of stability, that sh inclines, much under sail and besides the reduc effectiveness of the sail for its purpose their pla is brought to be so oblique to the perpendicul that the effect of the resolved thrust of the wi on them, particularly when it is strong, as it tl curves the sail much more, is to press the s own and over, so that it needs the concurrenc only a small wave to immerse her side more dangerously if it does not overset her, under any circumstances making her strain, sometimes leak, or ship water, which tends to increase the list. See Fig. 15.

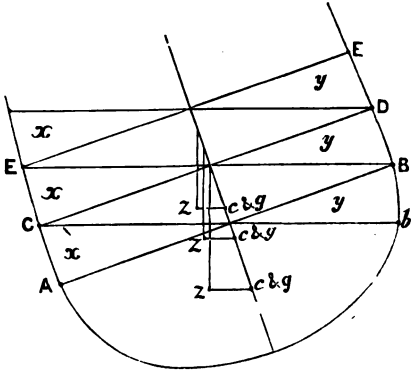
I have known ships to sail faster in racing on the sails being reefed, as this admitted of the sails being set flatter; it always pays to reef in time, not waiting till the wind becomes too strong to admit of sail being off except by being blown away, at all times a dangerous experiment to hope for.

The position of the centre of gravity being all important, and the difficulty of entering into a detailed estimate of all the points changed, by cargoes varying in specific gravity and quantity, is so great, that it is most desirable to give a rule that will apply to all cases that shall, though not always strictly correct, be safe and effective.

This is, that the centre of gravity with light cargoes, shall be brought, by ballast placed on the floor, down to the centre of figure of the body immersed by such cargo, and the centre of gravity brought up to the centre of the figure immersed by the heavy cargo.

Let Fig. 12 represent these states of loading, *A B* the load line in the first case, *c* and *g* represent the height of the centres of figure and of gravity, *Z′* the new centre when the vessel is

Fig. 12.



inclined, $Z\ g$ will then be the lever of stability. Suppose now $C\ D$, the second water-line when upright, now as x' and y' bear a smaller relation to its total displacement than x and y to its displacement, z' will move out a shorter distance than z from c, the lever $z'\ g'$ will be shorter, but as the weight by which it is to be multiplied is greater because of greater immersion, the stability in the two cases will be about equal. Let $F\ E$ represent the water-line in the third case. Here again, as x'' and y'' bear a smaller ratio to the whole displacement than x and y did to the least displacement, z''

will move out a shorter distance, and the lever $z'' g''$ will be still shorter than in the two previous cases, but then it will have to be multiplied by a greater weight, so the stabilities in each of the three cases will be about equal.

If the proportionate breadth to length was unusually small, the centre of gravity were better lower than the above rule would indicate, and if the proportionate breadth were unusually great the centre of gravity were better higher up than the above rule would indicate.

To facilitate such adjustments, builders should be compelled to furnish, and indeed mark, the heights of the centres of figure for each water-line 6 inches apart within the range of the light load and deep load lines.

It would be foreign to my purpose to enter into detail as to stowage: for that we must refer to "Stevens on Stowage." Our purpose is to confine it to that which affects the conduct and safety of a ship at sea.

It will be remembered that we shewed, Figs. 1, 2 and 3, that all the pressures are on the bottom, and that the amount of pressure upon any one point, owing to the law of gravity, and that of fluids seeking their level, is equal to the weight of the column of water above it; for the integrity of the ship the cargo should be distributed according to these *water pressures*: for, if not, the ship will be strained. In paddle steamers, owing to the excess of weight amidships over the upward pressure, they sagged at that part, and the reverse in old ships with flaming bows and heavy raking sterns, they fell at the ends. In a seaway that tended further to strain them, and produce leaks; improper distribution of heavy cargoes must involve danger in proportion, and more so if the ship is weak and old.

If there is a disproportion it should be towards the middle line lengthwise, where the ship is strongest. We have already stated the due height for the centre of gravity, we add, weights lighter than water should not be placed below and heavy above, except it be dunnage, or to raise ore or other compact dead weight if the whole cargo is thus composed, to raise the centre of gravity to the point specified.

Besides the evil of straining the fabric, excess over upward pressure should not be in the extremities: for though these, *in comparatively smooth weather*, might tend to limit angles of pitching and scending, yet, especially in bad weather, once set in motion, the greater momentum of these excess weights would make the pitching deep and violent. Moreover, as the lifting power would be deficient in proportion as the weight was in excess, the vessel would not lift at once to the sea, and it *would break* over her, she would ship water, and all the evils would be increased. It should be remembered that the propelling power depresses or buries the bows, therefore everything should be done *not* to increase the tendency to pitch deeply.

Heavy weights, or weight in excess of the upward pressures, should not be placed at or on the sides, when it can be avoided: for, besides the tendency of such to strain the ship's fabric and cause her if weak to leak, when a wave comes at *first* its lifting power is not sufficient to overcome the inertia of the excess of weight, it therefore accumulates and lifts the side quickly, which is objectionable, or it breaks over her and causes her to ship water.

When set in motion, and she must accommodate herself more or less to the passing wave or hollow, as we shall shew, the momentum of these weights must carry her through larger arcs, larger in proportion as the upward pressure is less than the weight above it.

For these reasons iron-clads should have flat floors, and be as deep draughted as circumstances and their intended use will admit, that the upward water pressure near the sides should be as great as possible.

All other things being equal this form will roll through least arcs, as the pressure alluded to tends to limit the arcs of roll.

Previous arguments proceeded on the assumption of smooth water; this condition is exceptional: we therefore must consider the effect of waves on vessels and the best mode of guarding against the evils they entail.

For this it will be necessary to describe the general action on ships in their midst.

The instability they produce, and not stability, as has been alleged by a prominent modern theorist, is the cause of rolling motions. The danger from waves cannot be too sedulously guarded against, especially against that occasioned by those steep faced waves produced by strong winds with currents below running in the opposite direction, for these form an additional adverse couple. To vessels with little stability, these are a special danger on L'Aghullas Bank, the coast of Portugal, and some parts of our own coast.

Yet it is taught that "the effort of stability is "the lever by which a wave forces a ship into "motion, that if a ship were destitute of this "stability no wave that the ocean produces would "serve to put her in motion, whether that stability "were due to a broad plane of floatation or deeply-"stored ballast."

There is no foundation for this, for stability is the resistance which is offered to change from the vertical position, the effort of the fluid or gravity *to restore* the body to the rest it may have been *disturbed* from.

It is derived from two sources, a low position of the centre of gravity, and a broad plane of floatation.

If a vessel is inclined in smooth water both kinds will resist further inclination, or will seek to restore the vessel to the perpendicular at which she rested.

If the water-level be inclined, as in the case of a wave, that portion of the stability which is due to buoyancy will be exerted to bring the vessel's mast perpendicular to the wave surface on which she floats; in this process will be developed more and more that kind of stability which is due to deeply-stored ballast, or a low centre of gravity; under these circumstances the two kinds of stability are opposing, *not* concurring, forces, as has been taught.

One tending to bring the vessel's mast perpendicular to the wave surface, the other perpendicular to the earth, actuated by the force of gravity.

Therefore all calculations made on the hypothesis that stability is the cause of motion, as is done by some modern theorists, must be erroneous. Indeed these calculations are more erroneous than represented above, for they are made on a further erroneous hypothesis that the inclinations are round a comparatively fixed point in the middle longitudinal line of the ship and the rolling motions likewise!

Yet this not true in smooth water, and is always untrue of all ships in a seaway.

The breadth is a lever through which stillwater acts on a ship to produce *rest*, and also through which waves act to produce *motion*, but this is a different thing from stability, being the lever that produces motion, simply because breadth, under totally different circumstances, is an element in producing stability. Stability is an effect in this case, not a cause!

Rolling motions of ships in a seaway are produced by the alternate rise and fall of the water supporting them, and the rise and fall of the floating body accommodating itself to new and changed conditions oscillates in search of, rather than possesses stability, hence the motion. *Motion* is the result of instability and rest the result of stability.

FIG. 13.

Suppose any ship floating in smooth water, as in Fig. 13, and waves to roll across her as waves rise *above* the mean level, and the hollows fall below it, a vessel in passing over the intervening spaces must rise and fall.

Thus, as the wave moves along it will lift the side of a ship next to it, and will continue to lift and incline her at the same time until she is brought into the position of *b*, this rise and inclination will be continued till her middle line passes

Fig. 13.

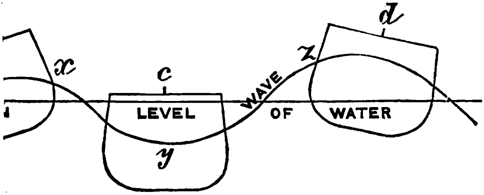
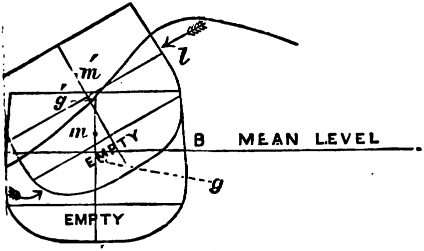


Fig. 14.



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the crest of the wave at x, then her upper side will begin to lose support, and the vessel will begin to fall; in a short time this will change the direction of her inclination, and she will roll over to the other side, and will fall till the middle line reaches the bottom of the hollow at y; then the lower side will begin to rise and to change the direction of the roll, gradually bringing the vessel into the position of d, and so on, as long as the vessel is in the midst of waves, all through one side being raised first, then the middle and then the other side, and falling in the same order, and it is obvious this process must take place irrespective of the stability being less or more, for the falling and rising must follow hollows and waves. Indeed though the wave is drawn across the vessel the lifting power is always on the bottom, therefore the higher the centre of gravity of necessity the more easily will the vessel be rolled and through larger arcs. Moreover, it is obvious that the point round which the body rotates is always changing, and is always outside the ship and at the opposite side from the moving force which operates first at one side, passes across, and then commences from the other side first.

FIG. 14.

Therefore the attempt to estimate the rolling motions from any power to resist inclination round a *fixed axis by* a lateral force, such as wind in smooth water, is misleading, and to assume an analogy between motions in the midst of waves and those produced by racing men from side to side, is delusive in the extremest degree.

The motion produced by waves must vary with their height, distance apart, and the greater or less rapidity with which they move across the vessel.

Moreover the shape of the wave exercises a great and important influence; this is always changing, the face is never the same as the back of the wave, and this difference is greatly increased by the strength of the wind. The size also of every third or fourth wave varies.

Weather currents and tides are exceedingly dangerous to vessels with little stability; these make the wave exceedingly wall-like in form, so much so as to be a certain danger to vessels with high centres of gravity, as these seas would readily throw such on their beam ends.

These circumstances, the extreme ranges of draught in steam vessels, from lessened specific gravity of cargoes, and other things, involve the advocates of high centres of gravity with little stability on any pretence, and it can be no more than a pretence, in the very gravest responsibility. It is time that we were delivered from that dangerous error, that stability, especially that due to a *low centre of* gravity, is a cause of danger, when, in truth, it is the prime element in safety—the only one that will save ships from capsizing!

A sufficiency is necessary for the proper qualities of ships as well as for safety; this is fully proved in the number of ships admittedly capsized because of its deficiency, and in the legislation as to deck loads.

The tendency of a low centre of gravity is to limit the arcs rolled through. This is established in the case of vessels laden with ore and other compact cargoes stowed low, from which their motions are so short and quick as to jerk their masts over.

Ships for the most part are more or less like a rocking-horse set in motion, the ship and point of rotation rising and falling as the ship possesses a section of greater eccentricity, this varies with the proportion of half breadth to depth—a circular cross section immersed to its axis is the easiest form.

The Bessemer scheme never could have succeeded because of this vertical motion, but to have put the machinery into a form of the extremest eccentricity, as was done, was to guarantee the completest failure.

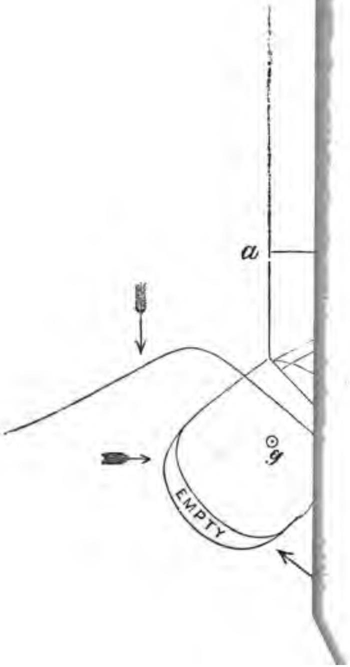
It will be asked, is there no case of synchronism when the motion of the wave concurs with that of the ship to roll her over?

Certainly! *but* it occurs when the period is long, with little stability from a high centre of gravity, for then the ship is easily rolled far by one wave, and is without power to return to little more than the upright position, when a second wave catches her, if pressed by sail and is on the face of a steep wave, she will be rolled over.

This was the case of the "Captain," from which a higher side would not have saved her, since she was not so much rolled round a central point *within* her as round one *outside* her, and at one side which lifted her up and pushed her over, facilitated by her *slipping** down the steep incline of the wave face, while pressed down by sail, also tripped up by the resistance and motion of the particles *below*, pressing in the opposite direction on her *empty* bottom which readily yielded to this pressure, so found its way to the surface, her heavy top sides finding their way down, the saved men getting out on her bottom.

The "Captain" had a period of 10 seconds doubtless increased under the heavy pressure of her sail when heeling 18°, failing altogether to recover

* All sailors will remember that in consequence of the *sudden* run down into the hollow from the face of a wave in a lee lurch, that the ship has shot out a wave from her side like that from the lee bow going 10 or 12 knots. The violence of this run down will be greatest when the *centre of gravity* is highest and the bottom most empty, all *other things* being equal.



a
g
EMPTY

from which a second wave struck her, lifted her over and turned her bottom up, and soon after went down with near 500 men.

FIG. 15.

Had she had sufficient stability instead of taking readily a perpendicular to the wave face, she would only take a mean between that and a perpendicular to the earth, consequently could not have been carried so far over as 18°, and would have had power to return to the upright quicker, so neither the second nor any succeeding wave would have thrown her over.

Another illustration of this danger is the following ship which was said to have "rolled abominably." Of her, these particulars are given:—

"After two or three weeks of rough weather "there was no question of the fact that the (latter) "vessel had rolled 45° to leeward and 13° to "windward."

Observations were made with pendulum and batten.

This ship's period was double that of the wave, and yet, contrary to Mr. Froude's theory, "she rolled from the crest of the wave."

"She rolled on her side continually, and yet the force of the wind could have inclined her only 2°."

Rolling on her side is evident from her rolling 45° one way *and* only 13° the other.

It is obvious that her stability was little.

How then account for her rolling on her side?

Having little stability, a steep-faced wave, partly by impact and by its lifting power, would raise one side first, then continuously aided by the wind and the fast-moving particles going in the same direction, would carry her beyond a perpendicular to the wave face, she would gravitate down this steep face, while the particles *below* moving in the opposite direction would trip her up, all together, forcing her to roll from the wave crest.

Then the moments of her masts, she being light, and her rolling to leeward with greater velocity, would tend to increase her roll to leeward by their increased momentum. Rolling back only 13° would arise from a high centre of gravity, thence little power to return, the particles *above* and those *below* would oppose for a time, and the moments of her masts would not be overcome so early as those of the ship, her period being double that of the wave, she would have made only half her roll when the next wave would catch her at the upright position, and roll her over on her side again, so we have little less than a synchronism, because her period is *too* long, *not* too short!

An increase of wind, or velocity, or size of wave would have rolled this vessel over, thanks to her *long* period! We ask of what use could sails be *to a ship in such* a condition?

This also is the explanation of the alarming condition reported of Her Majesty's ship "Volage," rolling 35° to leeward and 18° to windward, shipping green seas that washed men over her guns,—she also had so little stability that she inclined 14° when other ships inclined only 6° or 7°, yet she was one of those ships that had been ballasted, but not sufficiently. The charge brought against her captain of not putting more sail on her is preposterous, since she had then too much, more would have proved fatal.

Here we have a 2,000-ton ship in danger, while the 500 to a store-ship, with sufficient stability, was quite safe.

Illustrative of the evil of little stability, and therefore of long periods, we give the following ships:—

The "Crocodile"	Transport		40°
The "Northumberland"	9,000 tons, iron-clad....	7½ secs.	38°
The "Minotaur"	9,000 ,, ,, ...	7½ ,,	35°
The "Volage"	2,000 ,, unarmoured	10 ,,	53°
The Merchant Vessel above alluded to		10 ,,	58°

The metacentric heights of the iron-clads nearly
4 feet that of the others, with ballast about 2·5 feet.

It will be observed that neither the little stability, the long period, nor the weight of armour saves from large angles of roll, and yet the prime qualities of the ships have been sacrificed to obtain small angles of roll.

In the above arguments we have been considering for the most part the effect of waves on the beam of the ships; but it is very important to consider their action when the vessel is moving or hove to oblique to the line of the wave ridge.

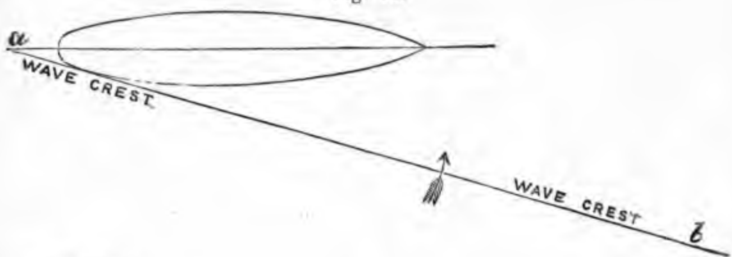
If the vessel is moving obliquely away from the coming wave and it overruns her, it will catch her on her quarter, which is the worst position, for, moving partly with the wave, she continues longer on the face of the wave, subject to its action, she will therefore be proportionably inclined by it.

FIG. 16.

Suppose *a b*, Fig. 16, to represent the crest of the wave moving in the direction of the arrows, if the stability is little, a short length of the wave will incline the ship, and will incline her more, as more of it reaches her side, the extent of the roll will be increased as the centre of gravity is high, and the bottom empty, the fast moving particles above pushing her over together with the wave, and the slow moving particles *below* pushing the lower parts in the opposite direction. She meanwhile is a longer time slipping down the incline of the wave face, tripped up by her keel and bilge keels, and most so when the bottom is empty, and therefore *easily yields* to this double pressure on it.

On the other hand, if she steers with her weather bow to the wave she shortens the time on the face or dangerous part of the wave, obtains proportional

Fig. 16.



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support from some longitudinal stability: this therefore is the proper course to steer.

In conclusion, we remark, that of the vast number of vessels that we have a record of, not one appears to have been rolled over because of having too much stability, while numbers are clearly lost every year from having too little, a further demonstration that the theory of rolling over by accumulation from synchronism is without foundation.

A very large proportion of those lost were vessels with cargoes liable to shift when the vessels are rolling, or by lee-lurching, and evidence is given that their cargoes did shift, evidence also is frequently given that when they are relieved of their masts or deck cargo, they have righted, sometimes too late as they have shipped much water, this clearly establishes that they were deficient in stability.

There have been a few cases recorded where the stability was too great in these cases, the masts have been rolled away, but the ships and crews have been saved, yet, according to the Froude-Reed theory, these should have been rolled over.

Vessels rolling less or more is a much more important question for merchant vessels than is supposed: for I do not think anyone can calmly consider the records in the "Wreck Register" and not be assured that the effect of this free water from leaks *is to* reduce the stability, give ships a permanent list, render them unmanageable, and finally lead to their being thrown on their beam ends and foundering.

Great stress is laid on the advantage of free water in the hold from shot holes and leaks as tending to reduce the arcs of roll, if this were true it would be a perilous idea to set afloat without explanation and caution, as it will lead men to think that it is advantageous not to pump ships quite out. Now, the effect of this free water in smooth water rolling may tend to reduce the arc of roll; but this cannot be the case in a seaway, for as it rolls to leeward with the lee lurch, like shifted cargo it will tend to throw ships on their beam ends; if at first it does not do that, it will retard her return to the perpendicular, thence the next wave will roll her further to leeward, and will exaggerate the roll if it does not help her over.

I can have no doubt but that it is an entire misconception to suppose that free water in the hold brings a vessel artificially rolled quickly to rest, the fact observed has been due primarily to the very great increase of vertical longitudinal area by an increased immersion, equal to four feet, down into comparatively or not easily disturbed water, to encourage the idea of value to free water in the hold is really to tell people that a reduction of a stability already too small is a safe experiment.

It cannot be doubted but that shifting of cargoes and leakage are amongst the most prolific causes of ships foundering in the open sea, and that these mainly proceed from the deep rolling and deep lurching we have shown to be much owing to insufficient stability.

All vessels carrying cargoes liable to shift, such as corn, seed, rice, or coals, should be obliged to have two perpendicular fore and aft bulkheads carried up as high as possible, these, while they would secure the cargoes from shifting, would so strengthen the ships and distribute the strain from the bottom, that ships would be far less subject to leaks and to disaster, and the cargoes would be less damaged in transit, I need hardly say it would effect a great saving of life. In fact, every one would reap a benefit from such.

The latest confirmation of these views, and those I have been advocating ever since the loss of the "Captain," has been brought before the public by the discussion relative to the "Inflexible." She has a stability represented by 8·5 feet of metacentric height, vastly greater than any ship that has been in the Navy, as great as that of the American monitors, and only less than that of the Russian circular ship, which has 8·9 feet, and yet the "Inflexible," without reason, is said not to possess enough stability, because, when nearly destroyed she is liable to capsize; why this is the inevitable *fate of men*-of-war, as I pointed out in my Lecture

D

on the Loss of the "Captain," page 30, unless th are made unsinkable; this has been in part a tempted in the "Inflexible," by cork, numerc cells, and other devices, none of which are to found in many vessels without any armour tl possess stability represented by only 2 or 3 feet

In new ships it is proposed to increase t stability much beyond that in the "Inflexibl and the importance of this recommendation is this, that it proceeds from the originator of t *little* or no stability theory and its supporters.

True, this increase of stability, not of the b kind, for it will make them more uneasy, is to pı vide for the effect of shot-holes, no merch ship requires so much, but water gets into th otherwise than by shot-holes, and when it does, they have *little stability*, they first become u manageable, and then founder; life and proper are lost, without any profit, nor any one single id to justify, for seamen and all nautical experien are opposed to the modern and unsafe theory th *"a ship to be safe must have very little init "stability!"*

In conclusion.—When alluding to Figs. 1, 2 a 3 we said that the upward pressures were unifor equal at equal depths, when the water was smoo and the two sides alike, the pressures would *equal on each* half of the body, therefore all the might be treated of as if there were but one passing up through the centre of the immersed figure, and that the pressure at any one point on the surface, where the pressures operate, is equal to the weight of a column of water, the height of which is the distance of this point from the mean level, and so the collective vertical pressures on the bottom are equal to the weight of the body.

These two pressures, the water, obeying the law of gravity, seeking its level presses up, and the weights in and of the vessel, obeying the same law, presses down with equal force and opposite directions; these rule all motions while the vessel is in smooth water, so we have dealt with them in all previous reasoning.

But when the water is disturbed as in waves, besides the disturbing forces of wind or steam or the helm, there are other water pressures, than those alluded to, that completely alter the problem. For the equality of the water pressures cease, and while the vessel is in the midst of waves, continually varying pressures come in, producing inequality in this respect.

This inequality varies with the height of the column of water on one side as compared with that on the other, *i.e.*, with the differences in height of the wave from hollow to crest.

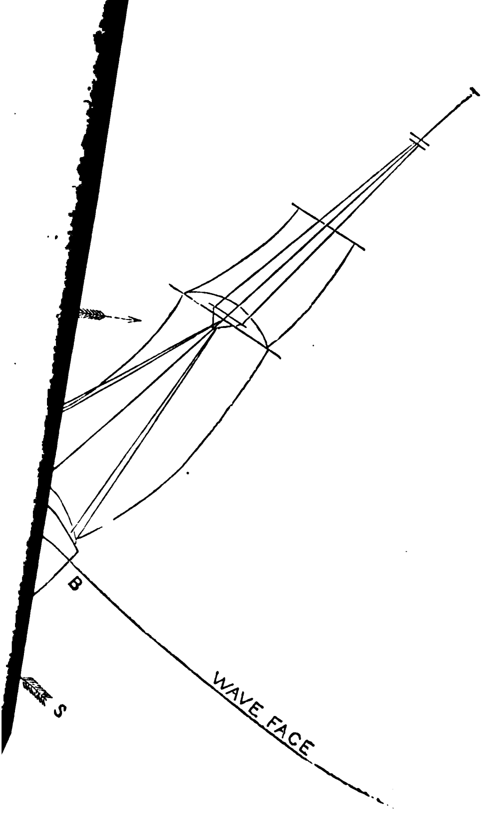
The effect of this altered column is to lift one side of the vessel, and in doing so to turn her round a point at the opposite side from the lifting wav force; this point changes from one side to th other as the wave moves from one side to the other i.e., when through the passage of the wave th vessel is changed from the face of the wave to it back. To make this clear, we will consider the tw sets of pressures separately.

First, we will assume the ship to be inclinin under a press of sail at the bottom of the hollow.

As the wave approaches it will commence to lif the upper side, and in doing so will incline th ship further from the vertical, rotating her roun a point outside the opposite side, still lifting her a it approaches: for by a beautiful provision it wi exercise its lifting power before it has arrive quite up to the side, did it not do so very many mor vessels would be swamped through not rising t the sea in time.

This lifting action extends to the whole vesse lifting her up on the face of the wave.

Let *a* and *b*, Fig. 17, represent two conditions first, that of a vessel in the hollow between tw waves inclined under the pressure of her sails, *i.e* by the force of the wind acting say at *t*, and th force of the water acting at *s* the centre of latera pressure two-thirds of depth down, forming couple to turn her round, and through the immer*sion of y* and the emersion of *x* moving *c*, th *centre of* figure when upright over to *c'* the centr b Fig. 17.



f figure when thus inclined. Now, g being the entre of gravity, $g\,z$ will be the distance of the ne of pressure down from the line of pressure up, r the lever in fact of stability, which, multiplied y the whole weight in tons, will give the stability hat she is putting forth at that angle of inclina-on in foot-tons.

Secondly, let us suppose the wave to have assed along and to have lifted the same vessel up n to the face of the wave. The question then rises, will a different form or distribution of 'eight tend to facilitate or hinder the extent of the bove inclining action?

Certainly!

This lifting action is indisputable, as every essel is thus inclined when in the midst of waves.

We will suppose *a* and *b*, Fig. 15, each to have qually *high* centres of gravity, and move the 'eight to be so concentrated as to admit of deep npty spaces at the bottom, this latter will occasion ne vessel to incline further; moreover, while being fted on to the face of the wave, and while on it, nere will be additional elements of danger.

The lifting action alluded to, is applied at *u* on he bottom first, and as it lifts, it relieves the other arts of the bottom, even across to the other side f some of these pressures, rotating the body as it loes so, round the point near A, Fig. 14, and o *the lee side* may not be in the least more immersed, therefore, no more stability is developed, as *c* would not move further out from *c′*.

Now, this lifting action will be greatest, 1st, when the wave is highest; 2nd, when the immersion is deepest; 3rd, when the floor is broadest; and, 4th, when, all other things being equal, the centre of gravity is highest, for then the lever *u g*, through which this lifting and turning pressure acts, will be greatest.

And the effect will be most dangerous when the bottom is lightest, for although the whole body is lifted, yet in the process, as the wave moves across, it turns the body or inclines it more and more until the crest or highest point of the wave has passed the middle line of the vessel, then the lower side commences to be lifted up, and the higher side to fall into the hollow, changing the direction of the roll, or, in other words, commences the roll back, that is assuming that she has not been rolled over.

Nor is the above the only danger on the face of the wave, for as the vessel then is on an inclined surface, she will gravitate down it, the upper part faster, both because the centre of gravity is high, but because the stream of particles helps rather than hinders that which the water below resists, with intensified force as it is more low (see *S*, Fig. 17), and acting on a light bottom that easily yields to this excessive pressure, tending, together *with the lifting* action on the other side at *u*, and *the wind couple*, to capsize the vessel.

Thus, without the addition of an under tow or stream running to windward below, or the action of the lee helm, which would increase the pressure at S, or the centrifugal force of a high centre of gravity, all which would incline the ship more, the mystery would be not that such a ship was capsized, but that she should escape without being so.

This fully explains why vessels with high centres of gravity, and worse, with empty ballast tanks on their floors, or with deep empty bottoms, as the "Captain" had, should have been thrown on their beam ends, or should have capsized.

We must beg attention to the fact, that on the occasion of the "Captain's" capsize, the highest recorded angle of inclination was only 18°.

No doubt a vessel will go over and return from angles double the amount of the above, and more, *if* the causes of danger above mentioned do not concur. But till we have a guarantee that they cannot concur, little stability will not be justifiable, even though it gave some benefit in another direction, but as absolutely nothing but injury can arise from little stability, the practice of giving little should be denounced with intense earnestness, as damaging and most dangerous, whether it proceed from the ignorance of the Naval Architect, or the insensate grasping of the Shipper.

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